College of Arts and Sciences / Department of Physics

Measurements of intrinsic magnetism in multilayer graphene using cantilever magnetometry

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INTRODUCTION & MOTIVATION

Graphene is widely regarded as one of the most promising emergent materials, of great interest for fundamental physics as well as for engineering applications due to its extreme properties. However little is known about the intrinsic magnetism of graphene, which must be understood if it is to be optimally integrated with technology. Fundamental to this study is the method we have developed to successfully transfer mesoscopic-sized graphene layers onto micro-mechanical cantilevers, in combination with the technique of cantilever torque magnetometry.

AIM

The purpose of this study is to:

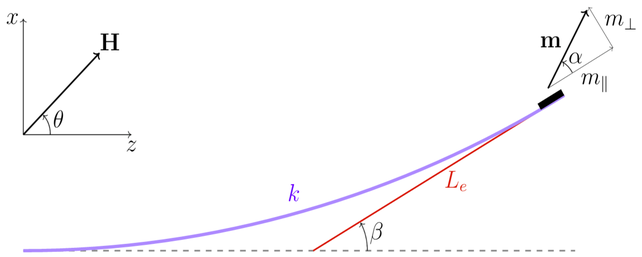
- Develop a technique to transfer mesoscopic materials onto cantilevers
- Make ultrasensitive measurements of magnetic moments of graphene
- Obtain crucial data of the intrinsic magnetism of single and multi-layer graphene

THEORY

The intrinsic magnetism of graphene is quantified as the magnetic susceptibility. In the presence of a magnetic field, the Zeeman interaction causes a measurable frequency shift.

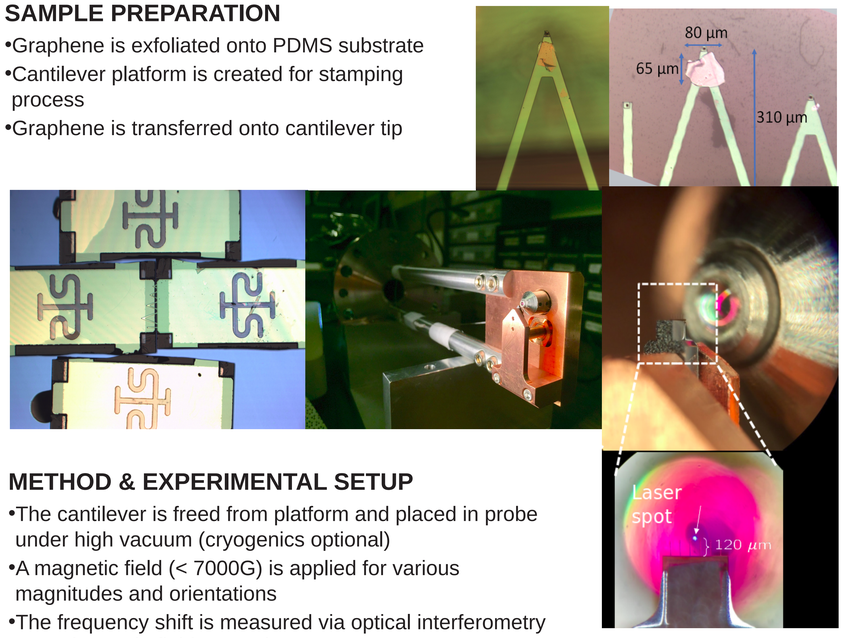
$$\frac{\Delta\omega}{\omega_0} = \frac{\mu_0 V H^2 \cos(2\theta)}{k L_e^2}\left(\chi_\parallel - \chi_\perp\right)$$

k = spring const. V = volume L_e = eff. length
$\{\chi_\parallel, \chi_\perp\}$ = mag. susc. μ_0 = vacuum perm. ω_0 = natural freq.



SAMPLE PREPARATION

- Graphene is exfoliated onto PDMS substrate
- Cantilever platform is created for stamping process
- Graphene is transferred onto cantilever tip



METHOD & EXPERIMENTAL SETUP

- The cantilever is freed from platform and placed in probe under high vacuum (cryogenics optional)
- A magnetic field (< 7000G) is applied for various magnitudes and orientations
- The frequency shift is measured via optical interferometry at each step in field strength

Measurements at Room Temperature

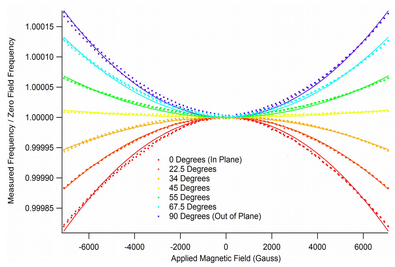


Figure 1:
Frequency vs. field data of 300-Layer graphite at room temperature.

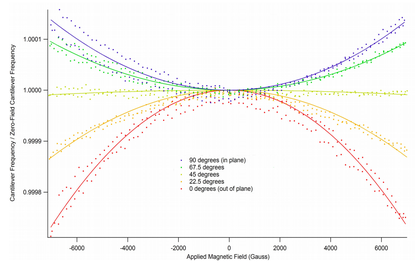


Figure 2:
Frequency vs. field data of 6-Layer graphene at room temperature.

RESULTS

- At room temperature we obtain parabolic curves for 6 and 300 layers as predicted theoretically.
- At low temperature we observe de Haas-van Alphen oscillations in the magnetic susceptibility of the 300-layer graphite.
- The 6-layer graphene shows no oscillations at high laser power (10nW) and spurious data at low power.

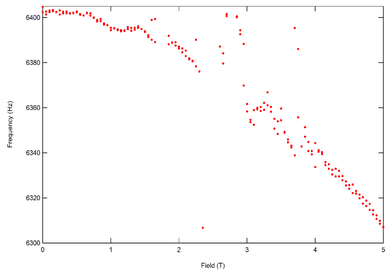


Figure 3:
Frequency vs. field data of 6-layer graphite at low temperature and low laser power.

Measurements at 4K

Figure 4:
Frequency vs. field data of 300-layer graphite at low temperature and associated residual.

Figure 5:
Residual vs. inverse field data of 300-layer graphite at low temperature.

CONCLUSIONS & FUTURE DIRECTIONS

Cantilever magnetometry indeed provides a mechanism by which one can observe the intrinsic magnetism of multi-layer graphene. In future studies, fewer-layer graphene and other 2D materials such as hBN and MoS2 as well as stacks thereof can be measured via the same method.

Figure 6:
Magnetic susceptibility vs. inverse field data of 300-layer graphite at low temperature.

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